

National Aeronautics and Space Administration

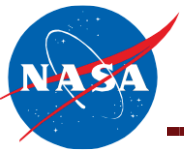
UAS Integration in the NAS Project ICAO Visit

Laurie Grindle

Project Manager, UAS Integration in the NAS Project

December 11, 2014



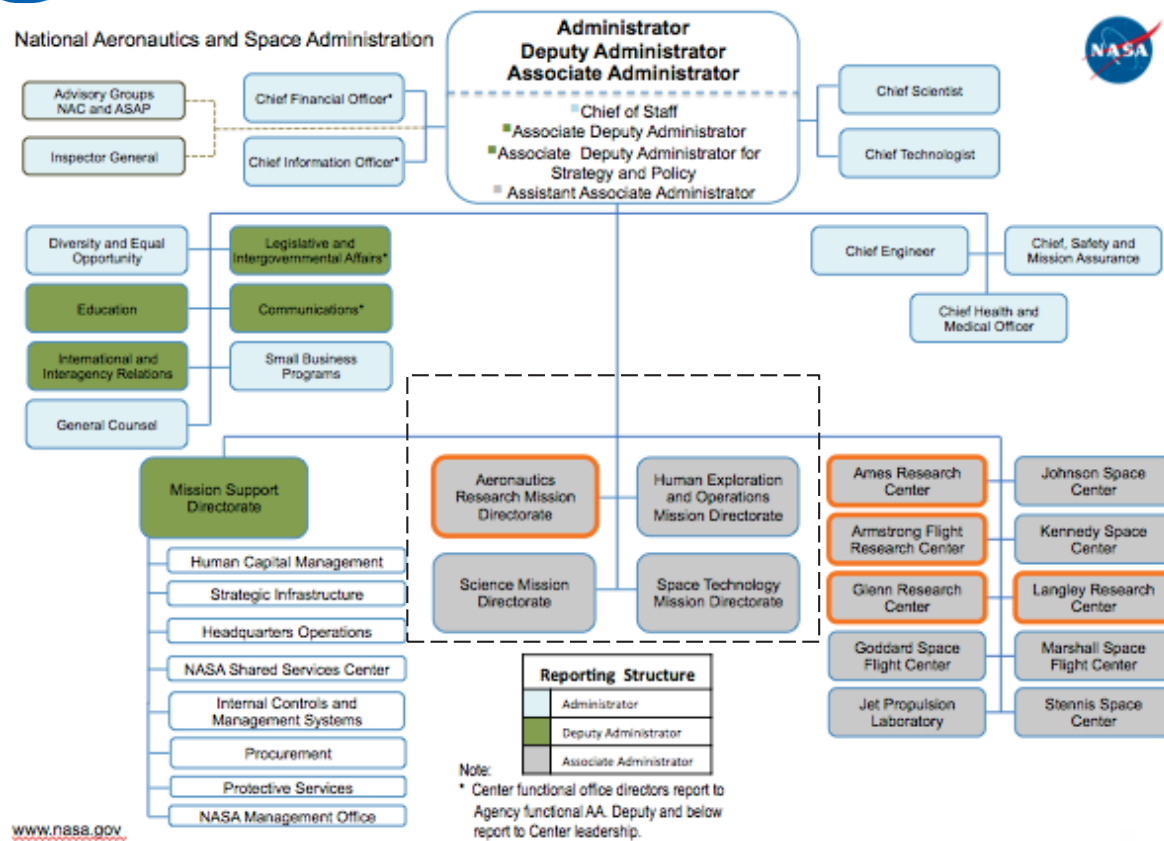


Briefing Outline

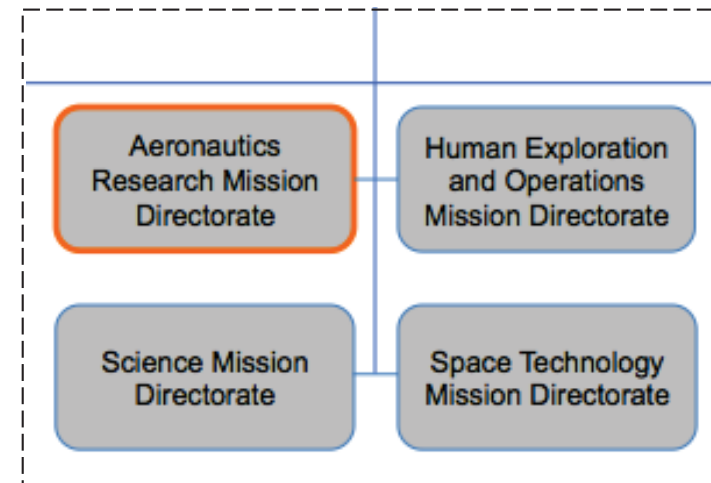
- UAS Integration in the NAS Project Alignment within NASA
- Project Overview
- Project Technical Challenges and Technology Development Approach
- FY14 Technical Accomplishments



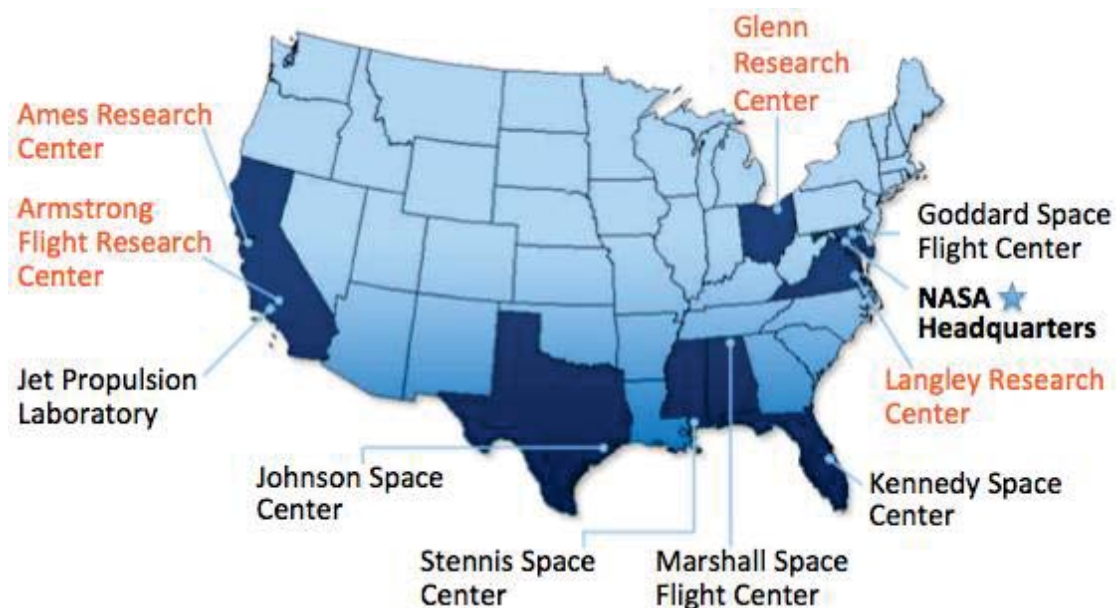
NASA Organizational Structure

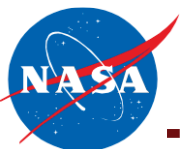


Mission Directorates



 **Aeronautics Research Centers**





NASA Aeronautics Portfolio

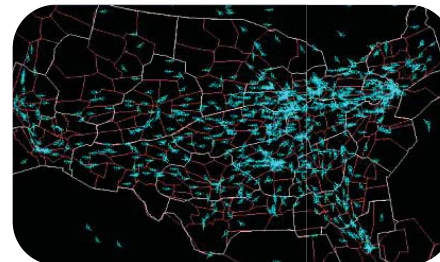


Fundamental Aeronautics Program

Conduct cutting-edge research that will produce innovative concepts, tools, and technologies to enable revolutionary changes for vehicles that fly in all speed regimes.

Integrated Systems Research Program

Conduct research at an integrated system-level on promising concepts and technologies and explore/assess/demonstrate the benefits in a relevant environment

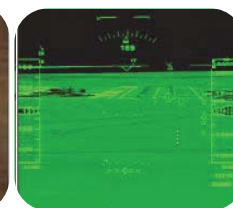


Airspace Systems Program

Directly address the fundamental ATM research needs for NextGen by developing revolutionary concepts, capabilities, and technologies that will enable significant increases in the capacity, efficiency and flexibility of the NAS.

Aviation Safety Program

Conduct cutting-edge research that will produce innovative concepts, tools, and technologies to improve the intrinsic safety attributes of current and future aircraft.



Aeronautics Test Program

Preserve and promote the testing capabilities of one of the United States' largest, most versatile and comprehensive set of flight and ground-based research facilities.





NASA Aeronautics Portfolio

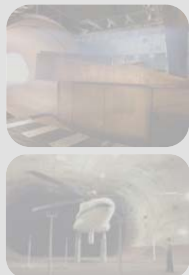
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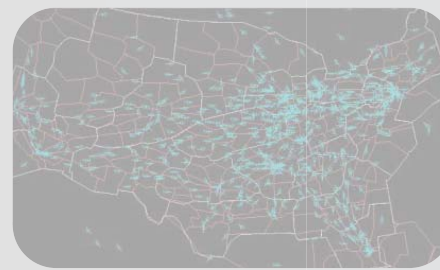
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Aviation Safety Program

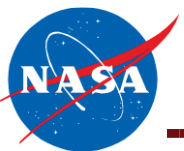
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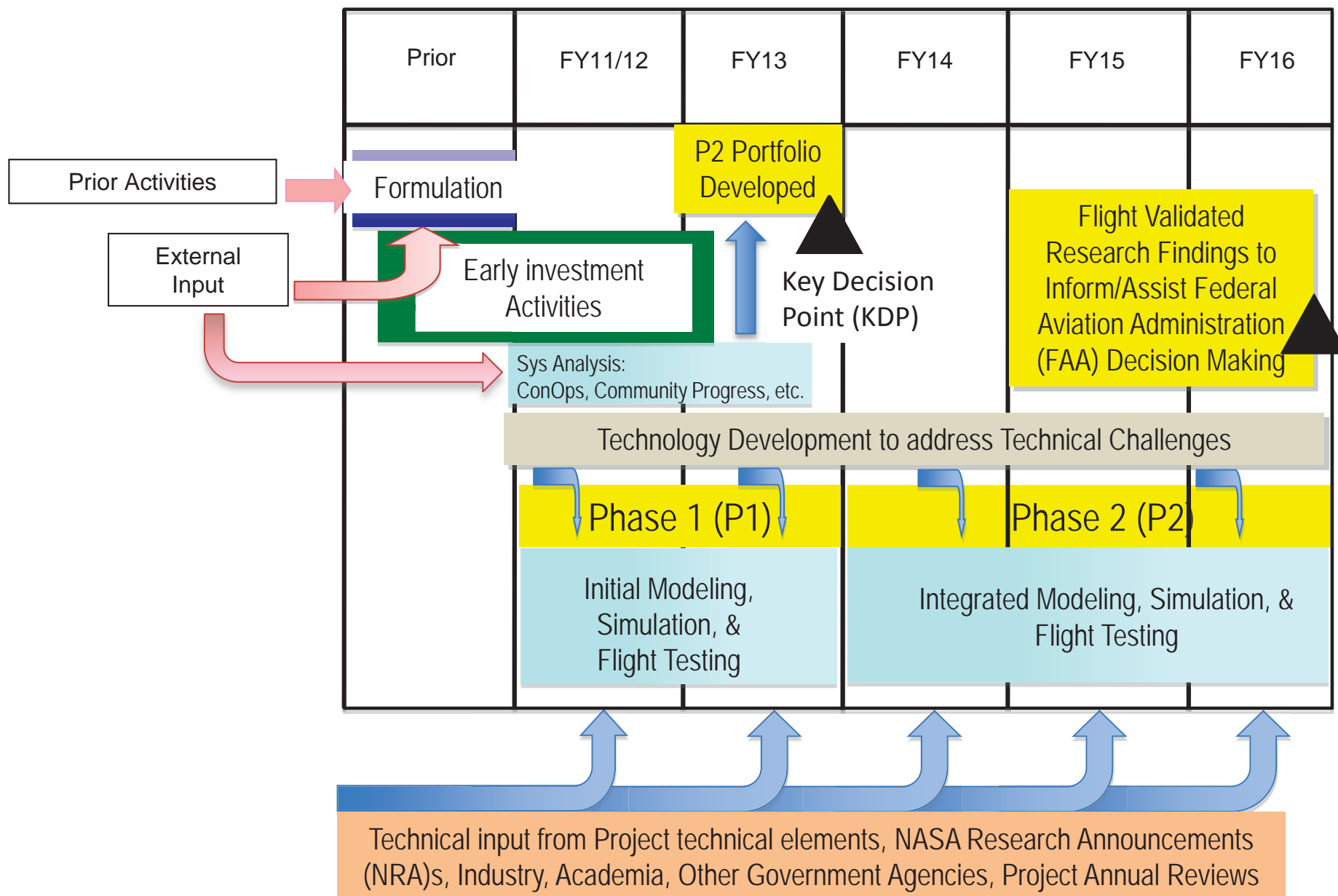
Aeronautics Test Program

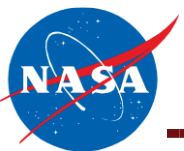
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UAS-NAS Project Lifecycle





UAS-NAS Project Formulation

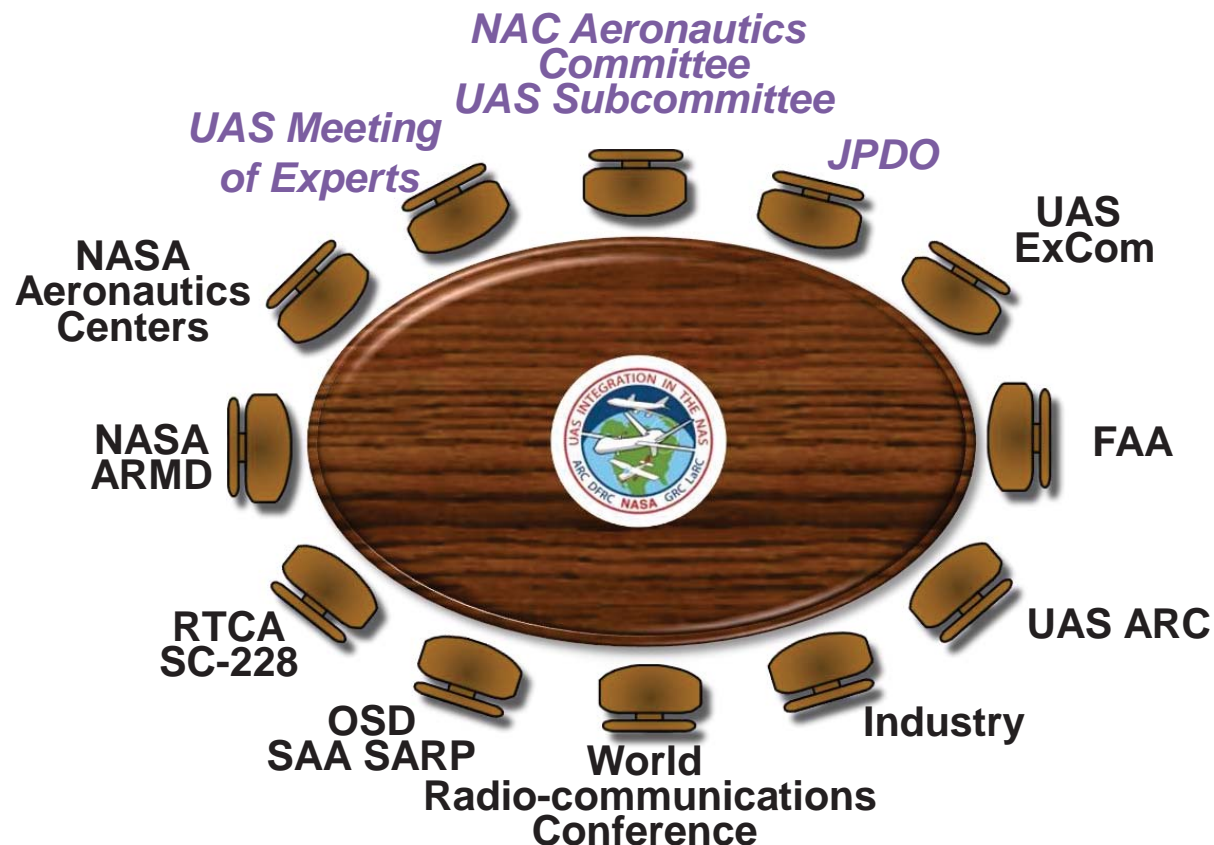
Key Stakeholders and Influencing Factors

Project Focus:

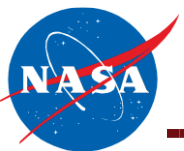
*Unencumbered NAS Access for Civil
/ Commercial UAS*



Key Stakeholders & Influencing Factors

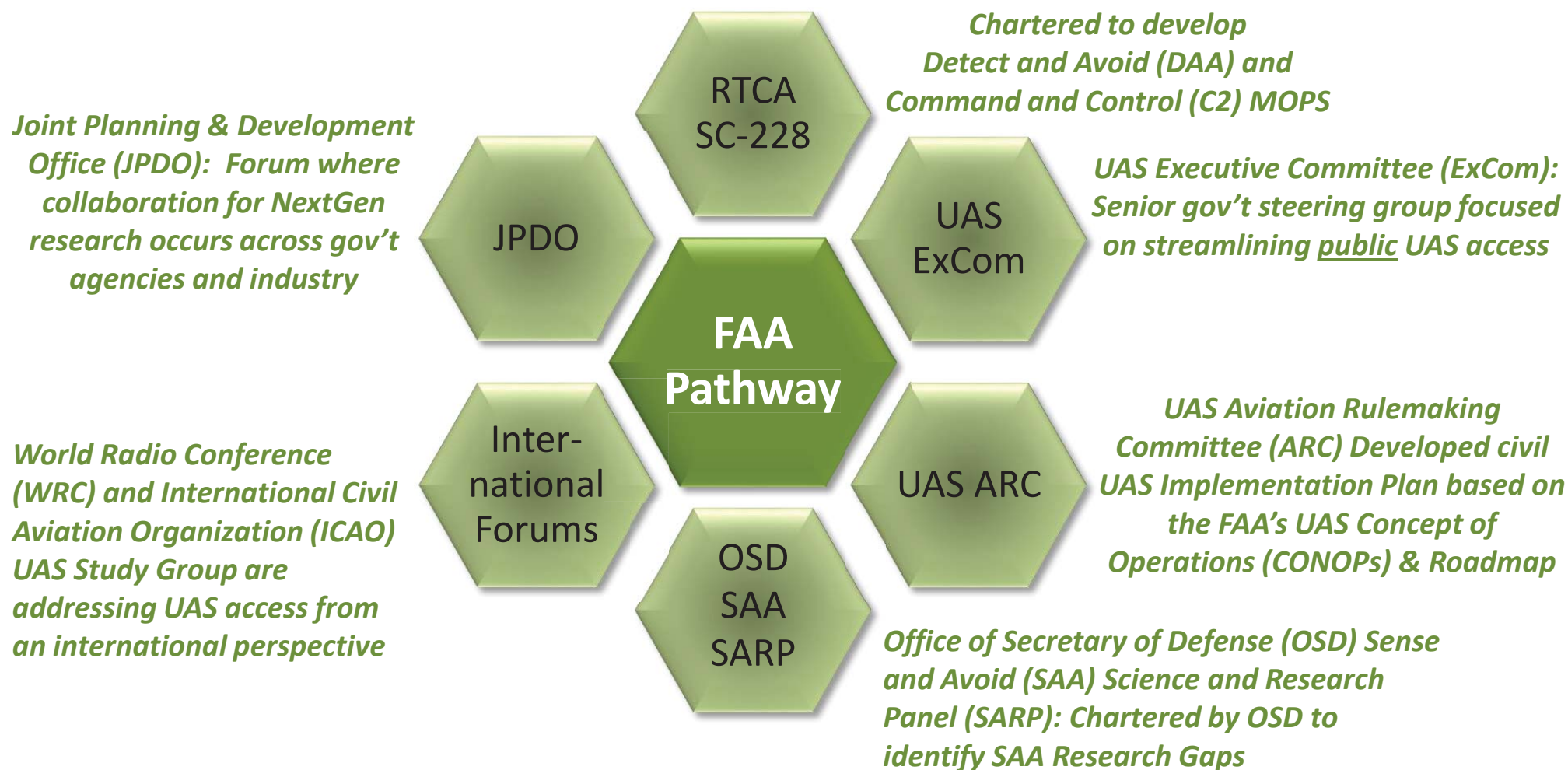


The NASA UAS-NAS Project is influenced by several key stakeholders within the UAS Community which helped guide it's formulation

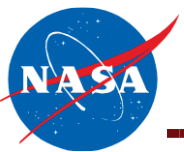


FAA Pathway to UAS Access

- The FAA is using several domestic forums, in conjunction with several international forums to lay out the pathway for their priorities and investments.



NASA has a leadership role within the domestic forums and participates in the international forums



UAS-NAS International Collaboration

- Communications
 - International Telecommunications Union (ITU) – WRC-15 AI 1.5
 - 2015 World Radiocommunication Conference – Agenda Item 1.5
 - ICAO Aeronautical Communications Panel
 - Participating in Working Group F (Spectrum)
 - Participating in Working Group S (Surface Air-Ground Datalink Communication System)
- Human Factors
 - ICAO Remotely Piloted Aircraft Systems (RPAS) Panel Support
 - North Atlantic Treaty Organization (NATO)
 - Human Factors and Medicine (HFM) working group 247
- John Walker (Contractor)
 - ICAO
 - Supports RPAS Panel as member of the FAA Team as a Subject Matter Expert
 - Supports preparation for ICAO RPAS Symposium/March 2015
 - Supports ICAO Regional forums (as required)
 - As required
 - NATO Flight Into Non-Segregated Airspace (FINAS) Work Group
 - Joint Authorities for Rulemaking on Unmanned Systems (JARUS)
 - Single European Sky Research (SESAR)
 - EUROCAE Work Group 73 & 93: UAS Standards Development
 - Civil Air Navigation Service Organizations (CANSO)
 - Mid Air Collision Avoidance System (MIDCAS) Consortium



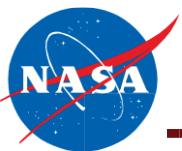
Goal: Provide research findings to reduce technical barriers associated with integrating Unmanned Aircraft Systems into the National Airspace System utilizing integrated system level tests in a relevant environment

Research Theme 1: UAS Integration - Airspace integration procedures and performance standards to enable UAS integration in the air transportation system

Research Theme 2: Test Infrastructure - Test infrastructure to enable development and validation of airspace integration procedures and performance standards

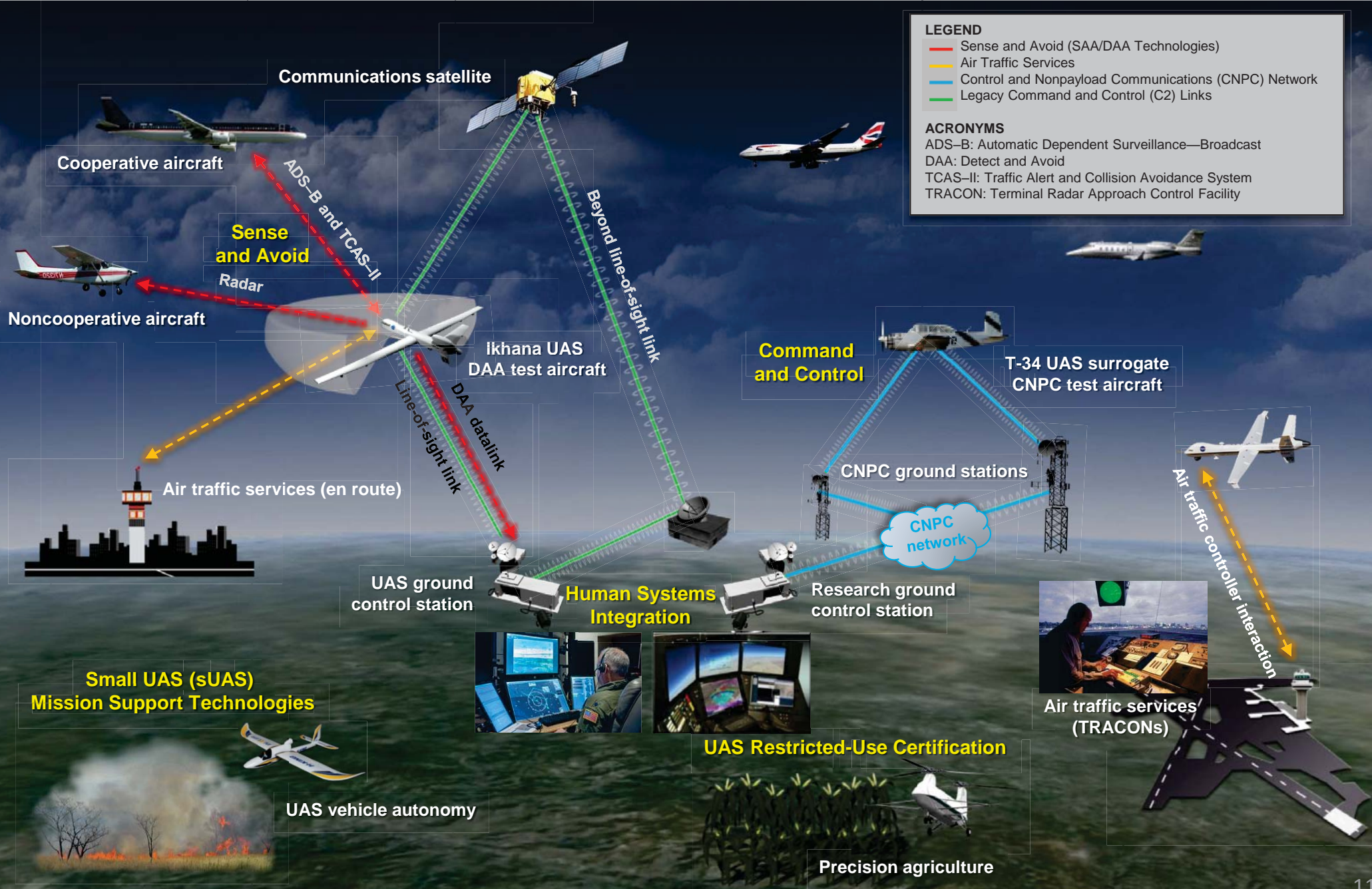


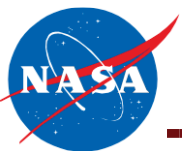
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UAS-NAS Project OV-1

IT&E Technical Challenge: Backbone for Integrated Testing





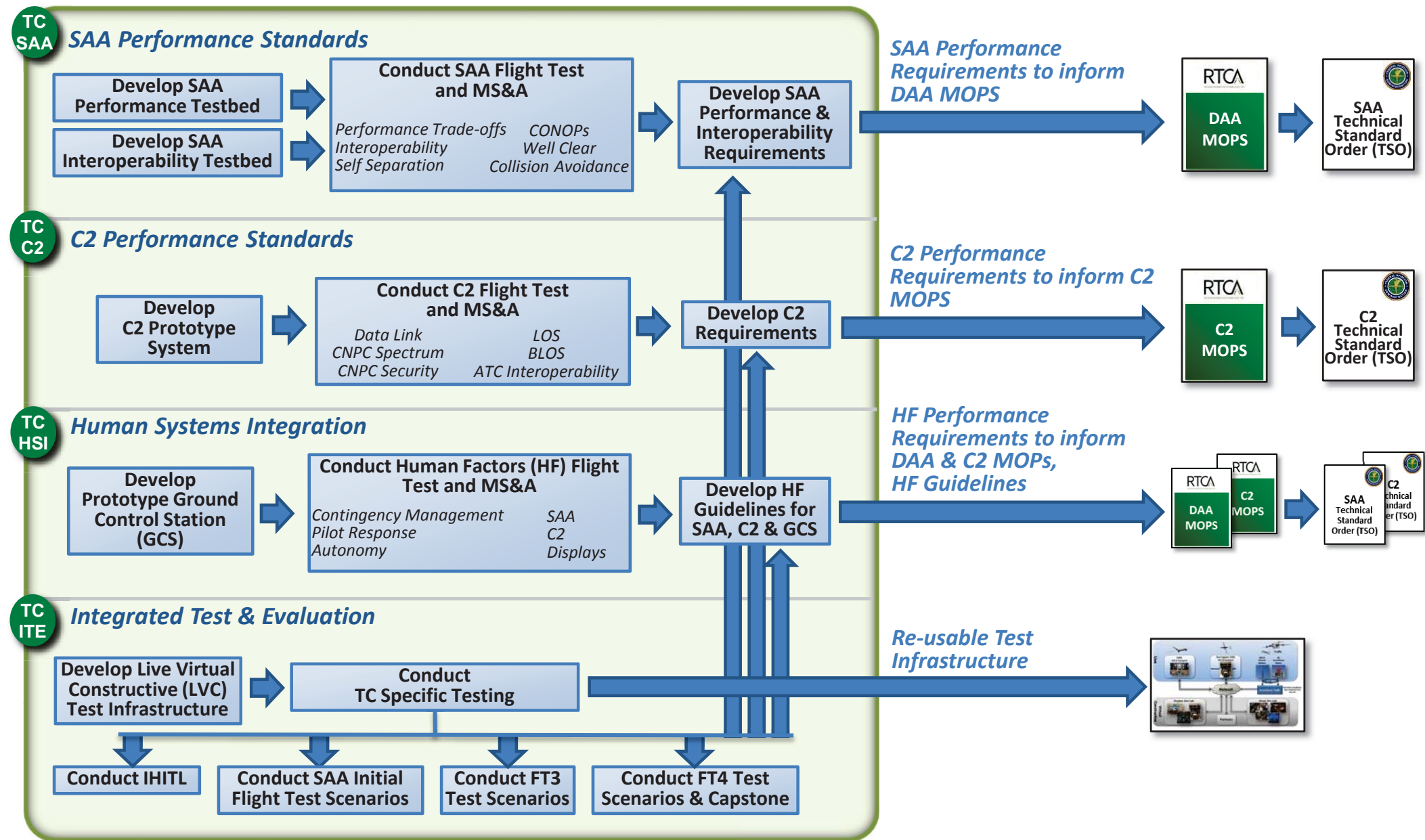
UAS Integration in the NAS Project

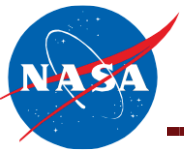
Technical Challenge Value Proposition

NASA UAS-NAS TC Project Activities

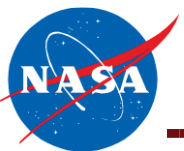
Key Products

Resultant Outcomes





FY14 Technical Accomplishments



Major Contributions to Stakeholders

- Office of the Secretary of Defense (OSD) Sense and Avoid (SAA) Science and Research Panel (SARP)
 - Provided one of three Well Clear Standards to SARP for assessment
 - Assisted SARP with
 - Definition of selection criteria: operational acceptability metrics
 - Data and analysis of three proposals against operational metrics
- SC-228 DAA and C2 Working Groups
 - Well Clear Definition
 - FAA provided recommended modification to SARP Well Clear criteria
 - FAA recommendation modified vertical dimension nearer to NASA proposal
 - DAA system requirements
 - DAA Verification and Validation requirements
 - GCS minimum display requirements
 - CNPC System performance requirements
- World Radio Conference
 - UAS Spectrum Analysis

Providing High Quality Products Meeting Stakeholders Needs



TC-SAA UAS CAS1 HITL

- **Research Activity Objective:**

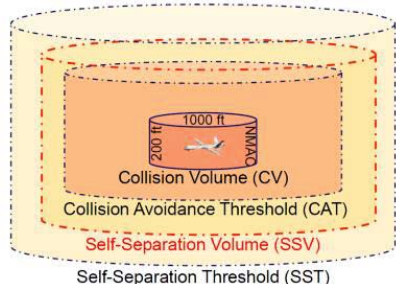
- Evaluate the impact of UAS SAA self separation maneuvers resulting for different SAA Well Clear volumes on controller perceptions of safety and efficiency



CV, CAT, SSV, SST and “Well Clear”



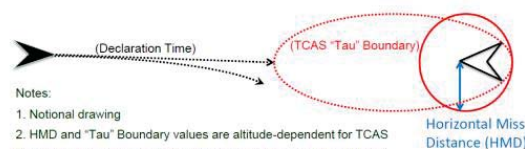
Workshop Model with NASA SAA Concept's Self-Separation Volume (SSV):



Note: CAT, SSV and SST boundaries are notional and generally not cylindrical



SAA “Self Separation Bands” Concept



Notes:

1. Notional drawing
2. HMD and “Tau” Boundary values are altitude-dependent for TCAS
3. Drawing assumes insufficient vertical separation (e.g., co-altitude)

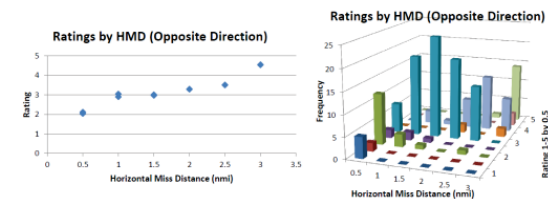
If Ownship trajectory will pass within HMD laterally of intruder then

- “Self Separation Bands” will appear on Ownship trajectory when within specified declaration time of the Tau boundary
- Pilot will need to negotiate a trajectory change outside of Bands

No Bands will appear on trajectory if it will pass outside of HMD



Ratings for Opposite Direction encounters Mean of 14 ATC subjects for each encounter



The plot above shows Mean Ratings for **opposite direction** encounters.

Plot of frequency of Rating responses for **opposite direction** encounters.

Note: All Horizontal Miss Distances required a UAS lateral maneuver (initially a collision course)

- **Interim Significant Results, Conclusions, and Recommendations:**

- A horizontal miss distance of ~1.5 nmi appears to be optimal for ATC acceptability (away from the airport vicinity)
- Horizontal miss distance of 1.5 nmi is 150% larger than the TCAS resolution advisory horizontal miss distance for all airspace below Class A, and 136% larger in Class A
- 500' IFR-VFR vertical separation (with no vertical closure rate) was universally acceptable during debrief sessions
- Air traffic controllers thought the SAA integration concept as presented was viable

Results Contributed to Well Clear Separation Standard & ATC Interoperability for DAA MOPS

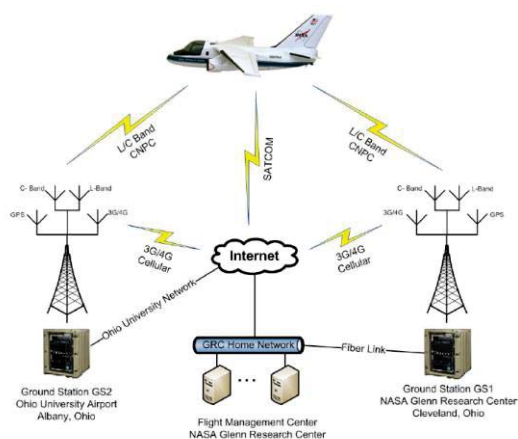


TC-C2

Gen2 Radio in Relevant Environment Flight Test

- **Research Activity Objectives:**

- Analyze the performance of the Gen2 C-band CNPC System prototype in a relevant flight environment



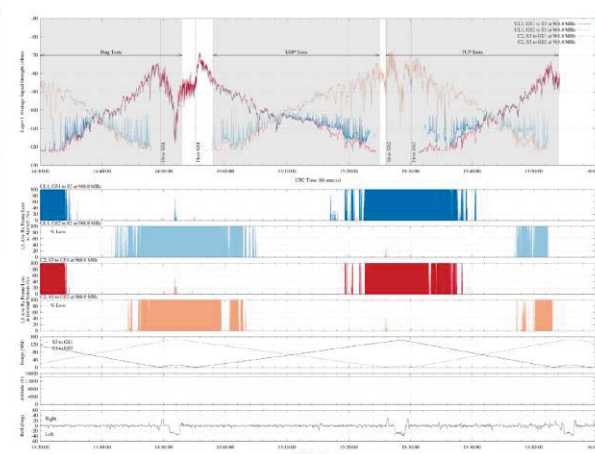
April 11, 2014

GS1 Characterization



April 30, 2014

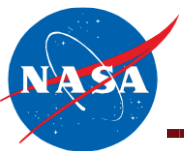
Two Ground Stations,
hand-off and data flow
tests



- **Results and Conclusions:**

- Demonstrated fluid transition “hand-off” of aircraft CNPC signal between two CNPC system ground stations
- Demonstrated operation of remote CNPC system ground terminals through network
- Measured data link transmission/reception times
- Testing of the Gen2 CNPC system demonstrated the ability to meet the initial SC-203 performance goals
- Results from the test were analyzed and delivered to SC-228, providing validation data and technical basis for the draft C2 MOPS

Results Contributed to CNPC Radio for Development and V&V of C2 MOPS

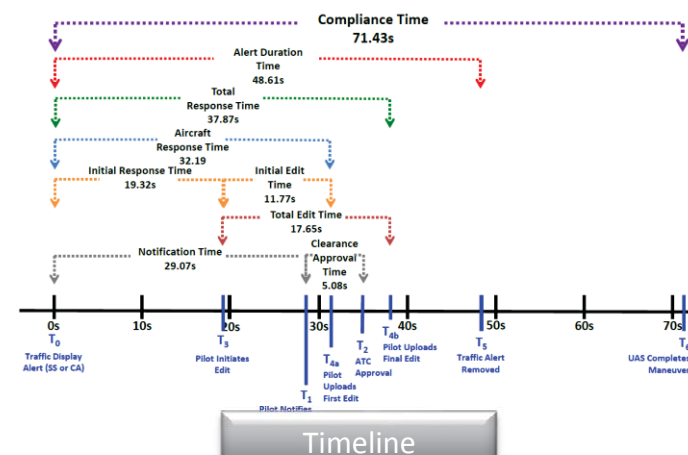
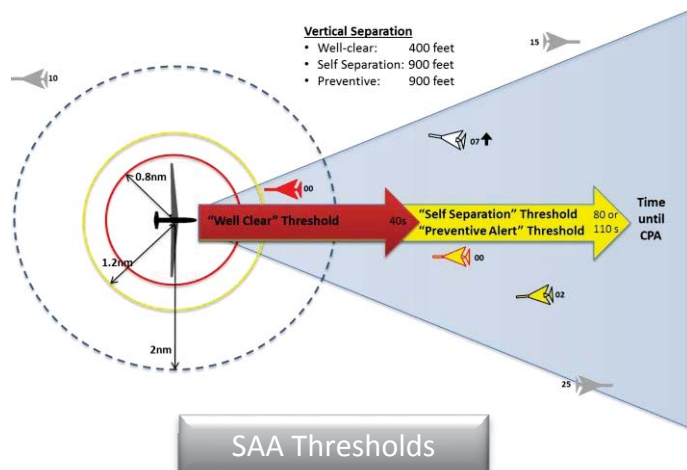


TC-HSI

Part-Task Simulation 4: SAA Pilot Guidance

- Research Activity Objective:**

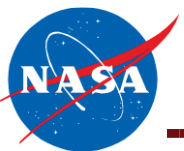
- Evaluate efficacy of minimum information SAA displays, potential improvements for advanced information features and pilot guidance, and integrated vs stand-alone GCS SAA displays



- Interim Significant Results, Conclusions, and Recommendations:**

- Consistent advantage seen for Advanced over Basic displays
- Overall, the Advanced displays had a faster Total Response Time compared to Basic
- There were no significant differences between the Standalone and Integrated condition
- Implications to Well Clear Violations and DAA Timeline need to be evaluated

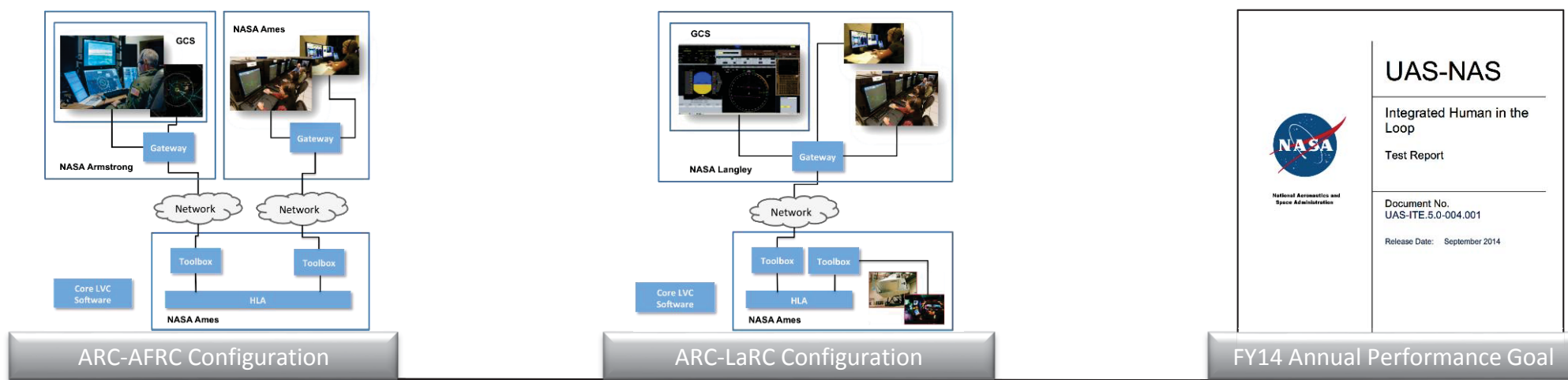
Results Contributed to GCS Minimum Information Guidelines/Requirements for DAA MOPS



TC-ITE IHITL Execution

- **Research Activity Objective:**

- Conduct a HITL simulation integrating the latest SSI algorithms, CNPC System model, and HSI displays using the Live, Virtual, Constructive test environment and document the performance of the simulation infrastructure in meeting the simulation requirements



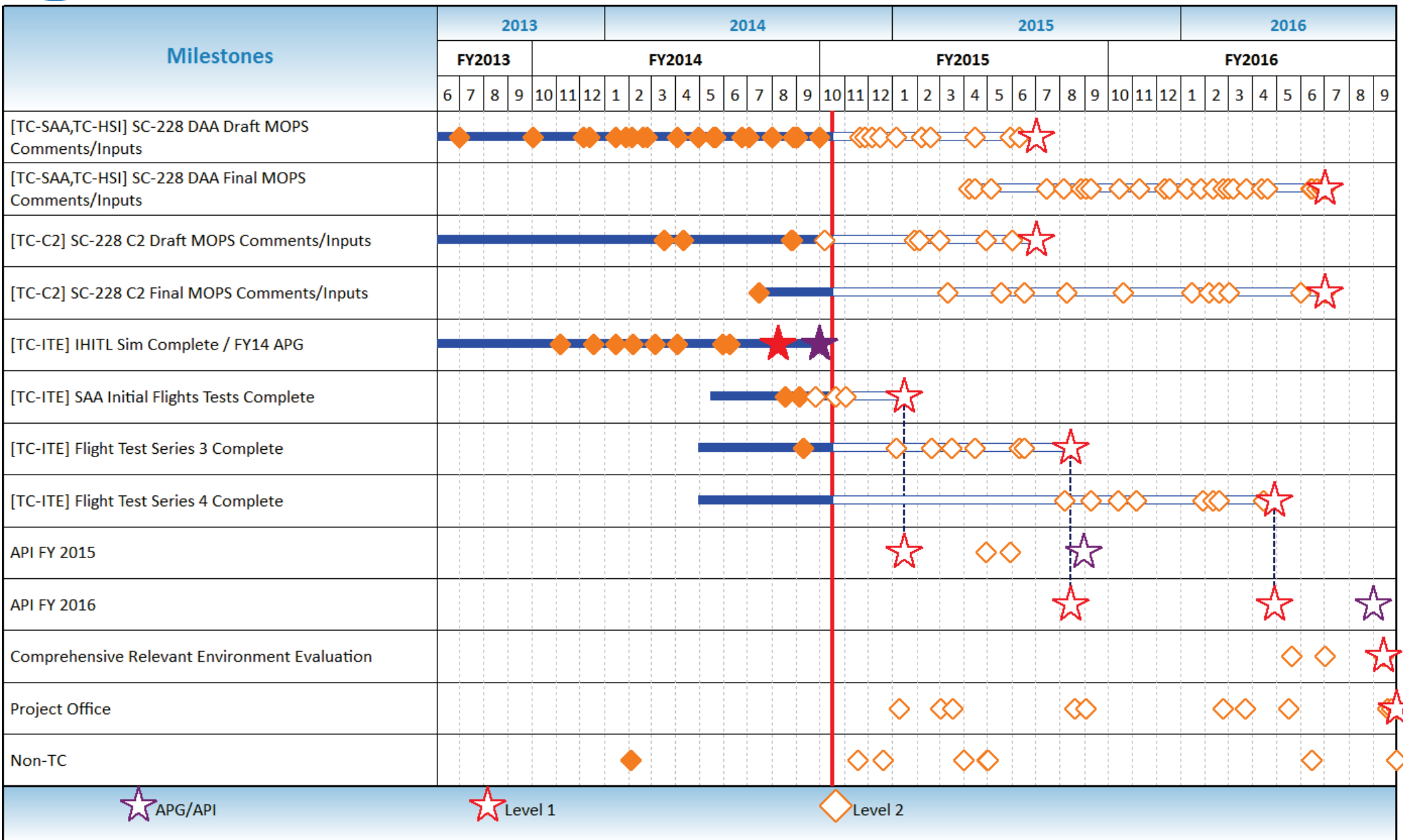
- **Interim Significant Results, Conclusions, and Recommendations:**

- IHITL successfully completed on July 25th
 - Data for each of the tests was successfully collected for all test subjects and archived at NASA Ames for researcher access
 - Distributed LVC test infrastructure thoroughly tested, though some software anomalies were noted, none significantly impacted data collection
 - Required data provided to researchers on schedule
- The simulation report documenting performance of the simulation infrastructure is on schedule

Results Contributed to Test Environment for V&V of DAA and C2 MOPS



UAS-NAS Milestone Summary

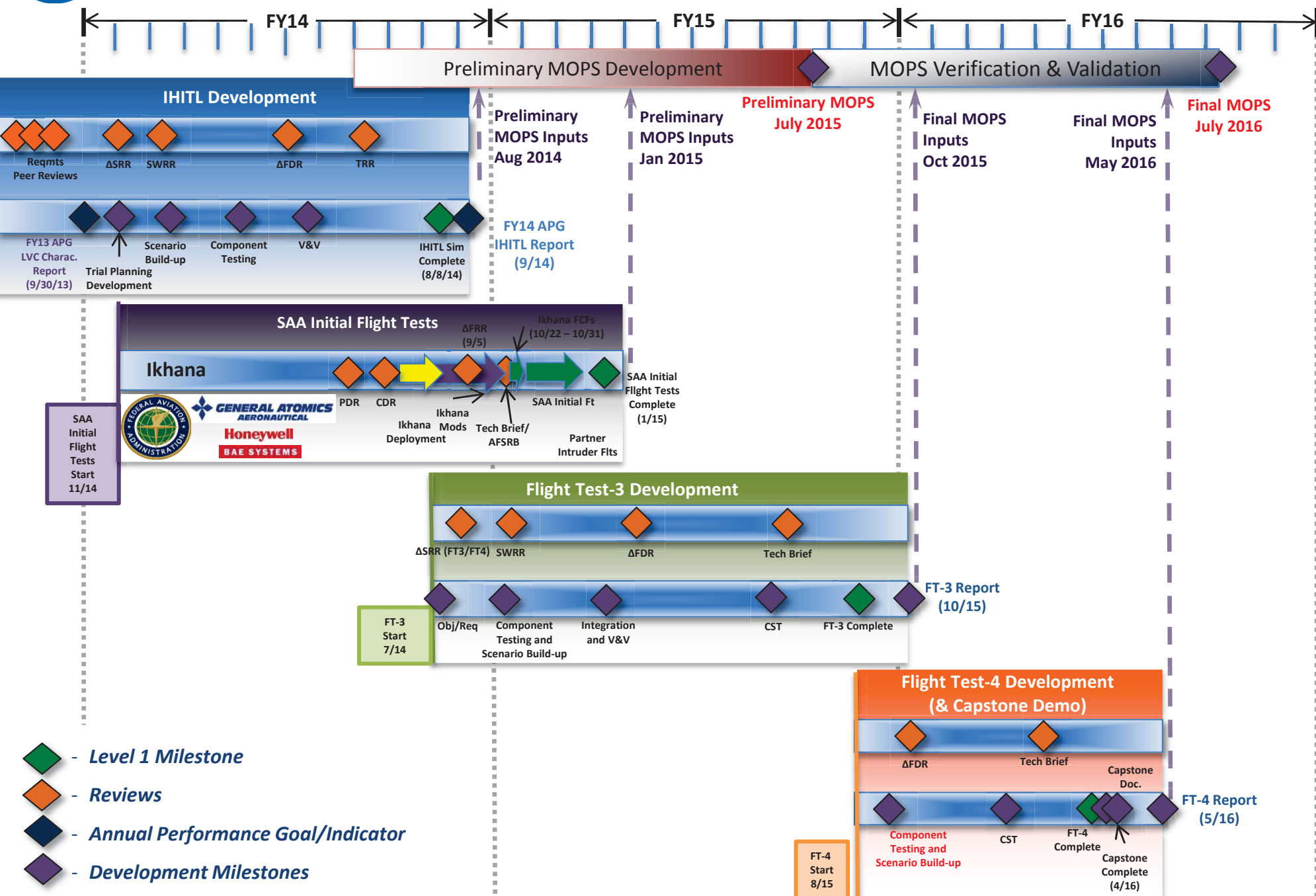


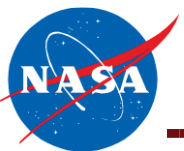


Backup Slides



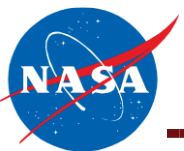
IT&E Integrated Test Flow





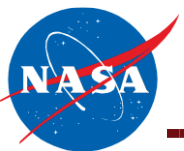
Acronyms

ADS-B	Automatic Dependent Surveillance - Broadcast
APG	Annual Performance Goal
API	Annual Performance Indicator
ARC	Aviation Rulemaking Committee
ATC	Air Traffic Controller
ARMD	Aeronautics Research Mission Directorate
ATM	Air Traffic Management
BLOS	Beyond Line of Sight
C2	Command and Control
CDR	Critical Design Review
CANSO	Civil Air Navigation Service Organizations
CONOPS	Concept of Operations
CNPC	Control and Non-Payload Communications
DAA	Detect and Avoid
ExCom	Executive Committee
FAA	Federal Aviation Administration
FINAS	Flight Into Non-Segregated Airspace
FRR	Flight Readiness Review
FT	Flight Test
FY	Fiscal Year
HF	Human Factors
HFM	Human Factors and Medicine



Acronyms

HITL	Human in the Loop
HSI	Human Systems Integration
ICAO	International Civil Aviation Organization
IHITL	Integrated Human in the Loop
ITE	Integrated Tests and Evaluation
ITU	International Telecommunications Union (ITU)
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
JPDO	Joint Planning and Development Office
KDP	Key Decision Point
LOS	Line of Sight
LVC	Live Virtual Constructive
MOPS	Minimum Operational Performance Standards
MS&A	Modeling Simulation and Analysis
NATO	North Atlantic Treaty Organization (NATO)
NRA	NASA Research Announcements
OSD	Office of the Secretary of Defense
P1	Phase 1
P2	Phase 2
PDR	Preliminary Design Review
RPAS	Remotely Piloted Aircraft Systems
SAA	Sense and Avoid
SARP	Science and Research Panel



Acronyms

SC	Special Committee
SST	Self Separation Threshold
TC	Technical Challenge
TCAS	Traffic Alert and Collision Avoidance System
TRACON	Terminal Radar Approach Control Facilities
TSO	Technical Standard Order
UAS	Unmanned Aircraft Systems
V&V	Verification and Validation
WRC	World Radio Conference